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Cover: Dorsal view of Mantis Shrimp *Cloridina ichneumon* (Fabricius, 1798) & *Gonodactylellus demanii* (Henderson, 1893). © Fisheries Research Station, Junagadh Agricultural University, Sikka.

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COMMUNICATION

Floristic studies on mangrove vegetation of Kanika Island, Bhadrak District, Odisha, India

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Abstract: This study pertains to the floristic composition of unexplored mangrove habitats of Kanika Island, Bhadrak District, Odisha, India. Six quadrats each measuring 31.62 x 31.62 m (0.1 ha) were laid at randomly selected sites in the Island between October 2019 and February 2020. Quantitative inventory yielded a total of 12 species across the sampled quadrats. Qualitative floristic inventory of the Island revealed a total of 20 species belonging to 17 genera and 13 families, including four true mangrove species, viz., *Avicennia alba*, *A. marina*, *A. officinalis*, and *Lumnitzera littorea* were evaluated as 'Least Concern' by the IUCN Red List. Out of 20 species, eight species were trees, followed by herbs (8 species), shrubs (3 species), and a climber. The study revealed that four species were true mangroves and 16 species were mangrove associates. *Avicennia alba* and *A. marina* were found dominant and have potential for regeneration in the island.

Keywords: Basal area, diversity index, importance-value, mangrove-associates, true-mangroves.

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INTRODUCTION

Mangroves are ecologically important coastal vegetation that is globally represented by 70 species (Polidaro et al. 2010), of which, 46 are present in India (Ragavan et al. 2016). The number of reported mangrove species in India varies from 34 to 69 (Untawale 1987; Banerjee 1984; Banerjee et al. 1989; Naskar 1993; Mandal et al. 1995). Such a variation in the number is mainly due to the inclusion of many mangrove associates in the list by various researchers. The mangrove vegetation of the east coast of India differs from that of the west coast. Mangroves of the east coast are larger with high diversity due to the presence of tidal creeks, canals, and brackish water bodies (Ahmed 1972). Mangroves are dynamic and its floristic composition reflects the health of the vegetation. Any changes in the floristic structure alter its functions and services (Alongi 2014; Krauss et al. 2014). Recent studies highlighted the importance of extensive floristic studies in understanding the diversity of true mangroves in different mangrove regions in India (Ragavan 2015; Saenger et al. 2019). Though conservation and management of mangroves have become a global priority, yet many of the mangrove patches within India are lacking baseline information (e.g., species diversity and threats) that are vital for their long-term management. Addressing such knowledge gaps will be imperative to improve our understanding of phytogeography, which can eventually contribute to the better management and conservation of this ecologically and economically important coastal ecosystem. I studied one such unexplored mangrove forests in Kanika Island, Odisha situated on the east coast of India. The objectives of the study were: (i) to quantitatively evaluate and document the species diversity, density, basal area, and IVI in the study area, (ii) to check whether there is any invasion by alien species into the island, (iii) to determine the dominant tree species, (iv) to enumerate the true mangroves and mangrove associates, and (v) to study the natural regeneration potential of dominant mangrove species in the Island.

MATERIALS AND METHODS

Study area

Kanika Island (20.830°N–86.985°E) is situated at the mouth of Dhamra River, which is the confluence of Baitarini and Dhamra rivers, in Bhadrak district of Odisha (Image 1). It has drying mud and sand flats covering an extent of 485 ha. The island has no human habitation. The district covers an area of 2,505 km^2 with the human population of c. 15,00,000 (2011 census) and agriculture and fishing are their major occupation. The average annual rainfall of the district is 1,530 mm and the average annual temperature is 26.8 °C

METHODS

The quantitative data on mangrove vegetation was collected by laying six quadrats (each 31.62 x 31.62 m) (0.6 ha) at sites (I to VI) on the Island by ensuring 300–500 m distance between each quadrat between October 2019 and February 2020. All the plant species were identified using Mandal & Bar (2018), www.plantlist.org, www.indiabiodiversity.org, & www.ipni.org and enumerated according to Manon (2006), such as trees (>1 m height) and juveniles (<1 m height). For trees and shrubs, the girth was measured at breast height using measurement tape and for herbs and climber, the girth was measured close to the ground. Vegetation data was quantitatively analyzed for species richness, density, basal area, and above-ground biomass based on the individual species enumerated in the quadrats. The excel data was used to compute community indices like Fischer's alpha diversity index, Simpson's diversity index (Simpson 1949) and importance value index (IVI). Data analysis was carried out using Biodiversity Pro Ver. 2.0. The dominance of species was calculated based on species IVI (Curtis & McIntosh 1950; Cintron & Novelli 1984). Above ground biomass (AGB) calculation was restricted only for trees and shrubs using diameter (D), height (H), and wood specific density (ρ) (species-specific) and using allometric equation of Chave et al. (2005). Study sites were determined using a Garmin Etrex 20x GPS device. Photography and videography was done using a Nikon P1000 digital camera. The collected data was tabulated, analyzed, and represented graphically.

RESULTS AND DISCUSSION

Qualitative diversity inventory yielded a total of 20 species belonging to 17 genera and 13 families in Kanika Island. Among 20 species, eight were trees, three were shrubs, eight were herbs and one was a climber. According to the classification of Barik and Choudhury (2014), four species were true mangroves and the remaining 16 species were mangrove associates. Fabaceae, with four species was the most species-rich family. Avicenniaceae was represented by three species, whereas families such as Malvaceae and Convolvulaceae had two species each.

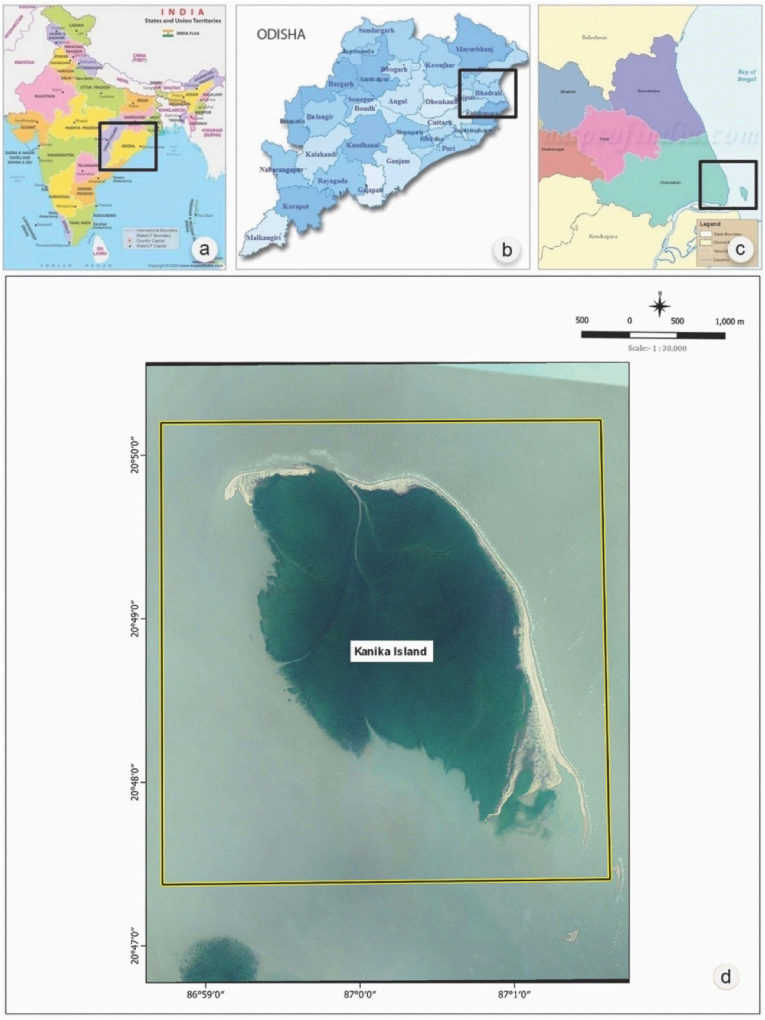

Image 1. Study area map: a—India map showing Odisha state | b—Odisha state map showing Bhadrak District | c—Bhadrak District map | d—Kanika Island map.

The remaining nine families were represented by only one species each. The genus *Avicennia* had contributed three species, *Ipomoea* represented two species and other 15 genera had contributed one species each. The study revealed that Kanika Island harbors only five mangrove species probably due to the small land cover (Table 1).

Species diversity

In the study area, sites V and VI with seven species each were the species-rich plots. The dry sandy elevated area of these plots supported more species of herbs and shrubs than the other plots that are primarily established on marshy areas. The probable reason is that true mangrove species grow in saline marshy areas, whereas sandy elevated areas support mangrove as well as associated species. *Acanthus ilicifolius* was found along the borders of creeks, canals, and marshes whereas the creeper *Ipomoea pes-caprae* and the herb *Sesuvium portulacastrum* were observed on the exposed elevated sand bars. Individuals of *Pongamia pinnata*, *Thespesia populnea*, and *Hibiscus tiliaceus* have grown on dry sandy areas in sites V–VI. *Derris scandens* was observed under the vegetations of *E. agallocha*. The remaining quadrats (I–IV) were laid in the marshy regions having creeks and canals, which naturally had homogeneous vegetation containing dominant species such as *A. alba* and *A. marina*. Blasco (1975) considered *A. marina* as the most salt tolerant mangrove species. The occurrence of *A. marina* as a dominant species on the island has corroborated the views of Blasco (1975).

Density

Maximum density of 4,750 individuals/ha was found in site-IV, followed by site-III with 1,670 /ha due to the predominant representation of juveniles of *A. marina* and *A. alba*. *Avicennia marina* had contributed to density of 246 individuals/ha in Bhitarkanika Wildlife Sanctuary (Upadhyay & Mishra 2014), 884 individuals/ha in Godavari delta mangroves (Venkatana & Rao 1993), 1,107

Table 1. List of plant species enumerated by qualitative survey in Kanika Island and their IUCN Red List Status

	Binomial	Family	Life forms	True mangrove (TM) or mangrove associate (MA)	IUCN Red List status	Native / Non-native
01	*Excoecaria agallocha* L.	Euphorbiaceae	Tree	MA	Least Concern	Native
02	*Avicennia alba* Blume.	Avicenniaceae	Tree	TM	Least Concern	Native
03	*Avicennia marina* (Forsk.) Vierh.	Avicenniaceae	Tree	TM	Least Concern	Native
04	*Avicennia officinalis* L.	Avicenniaceae	Tree	TM	Least Concern	Native
05	*Lumnitzera littorea* (Jack) Voigt.	Combretaceae	Tree	TM	Least Concern	Native
06	*Acanthus ilicifolius* L.	Acanthaceae	Shrub	MA	Least Concern	Native
07	*Thespesia populnea* L. Solander ex Correa	Malvaceae	Tree	MA	Least Concern	Native
08	*Hibiscus tiliaceus* L.	Malvaceae	Shrub	MA	Least Concern	Native
09	*Suaeda maritima* (L.) Dumort.	Chenopodiaceae	Herb	MA	Not assessed	Native
10	*Clerodendrum inerme* Gaertn	Verbenaceae	Shrub	MA	Not assessed	Native
11	*Ipomea pes-caprae* (L.) Sweet	Convolvulaceae	Herb	MA	Not Evaluated	Native
12	*Ipomea tuba* (Schl.) G. Don	Convolvulaceae	Herb	MA	Not assessed	Native
13	*Sesuvium portulacastrum* L.	Aizoaceae	Herb	MA	Least Concern	Native
14	*Pongamia pinnata* (L.) Pierre	Fabaceae	Tree	MA	Least Concern	Native
15	*Sauropus bacciformis* (L.) Airy Shaw	Phyllanthaceae	Herb	MA	Not assessed	Native
16	*Prosopis juliflora* (SW.) DC.	Fabaceae	Tree	MA	Invasive alien species	Non-native
17	*Derris scandens* Benth	Fabaceae	Climber	MA	Not assessed	Native
18	*Launea sarmentosa* (Willd.) Sch. Bip.	Asteraceae	Herb	MA	Not assessed	Native
19	*Canavalia rosea* (Sw.) DC.	Fabaceae	Herb	MA	Least Concern	Native
20	*Aeluropus lagopoides* (L.) Thwaites	Poaceae	Herb	MA	Invasive alien species	Non-native

individuals /ha in south-west coast of India (Sreelakshmi et al. 2018), and density of 1,731 individuals/ha in Coringa Wildlife Sanctuary (Satyanarayan et al. 2002). It indicates that the density of *A. marina* (662 individuals/ha) is lesser in Kanika Island than the other mangroves studied by Venkatana & Rao (1993), Sreelakshmi et al. (2018), and Satyanarayan et al. (2002).

Basal area

Basal area is an indicator for measuring forest-stand development, biomass, and productivity (Twilley 1998). The mean basal area of all the six plots was 3.137 (0.52±0.41). The maximum basal area (11.63 m^2/ha) was observed in site-I and the minimum basal area (0.14m^2/ha) was recorded in site-V. Site-I had more basal area than the other sites due to the occurrence of *A. marina* and *A. alba*. Out of 12 species enumerated, *A. marina* (0.993 m^2/0.6 ha), *A. alba* (0.889 m^2/0.6 ha), and *A. ilicifolius* (0.403 m^2/0.6 ha) had contributed to maximum basal area. Upadhyay & Mishra (2014) had recorded the basal area of *A. marina* (0.89 m^2/ha), *A. alba* (1.23 m^2/ha) in Bhitarkanika, whereas Venkatana & Rao (1993) had observed 3 m^2/ha for the same two species in

Table 2. Basal area, importance value index, and above ground biomass of mangroves on Kanika Island.

	Name of the species	Total BA (m^2)	IVI	Total AGB (Kg)
1	*Acanthus ilicifolius*	0.403	26.69	0
2	*Avicennia alba*	0.889	45.59	3757.53
3	*Avicennia marina*	0.993	126.91	3331.78
4	*Avicennia officinalis*	0.027	05.63	32.81
5	*Derris scandens*	0.011	11.53	0
6	*Excoecaria agallocha*	0.101	12.78	89.66
7	*Hibiscus tiliaceus*	0.080	12.78	59.23
8	*Ipomoea pes-caprae*	0.001	12.21	0
9	*Pongamia pinnata*	0.254	17.89	302.23
10	*Prosopis juliflora*	0.196	11.03	446.46
11	*Sesuvium portulacastrum*	0.002	07.16	0
12	*Thespesia populnea*	0.182	15.58	241.36
Total		**3.139**	-	**8261.06**

Note: Woody climber: Allometric equation by Schnitzer et al. 2006 (AGB= exp [-1.484+2.657 (ln (D)].
Trees: Allometric equation by Chave et al. 2005 for moist mangrove stands [GB= exp (2.977+ln ($_p$d2H)].
(AGB—above ground biomass | D—diameter | $_p$—wood specific density | H—height).

Godavari delta. George et al. (2017) had observed that the total stand basal area of mangroves of Kerala state was 20.33 m^2/ha. In the present study, the average stand basal area measured was 31.37 m^2/ha. It indicates that the mangrove stand density, biomass, regeneration capacity, and productivity of mangrove forest in Kanika Island is higher than the mangrove ecosystems studied by Upadhyay & Mishra (2014), Venkatana & Rao (1993), and George et al. (2017) and hence this basal area work is important for the present study.

Above-ground biomass

The present study on the mean above ground biomass (AGB) of true mangrove in Kanika Island reveals that the highest AGB of 3.757 tons/0.6 ha was recorded in *A. alba*, while the lowest AGB value of 0.032 tons/0.6 ha was found in *A. officinalis* (Table 2). But in Sunderbans, the AGB of *Avicennia* spp. was 101.9–118.7 tons/ha in 1991 (Choudhry 1991), whereas in 2014 it was 8.9 to 50.9 tons/ha (Joshi & Ghose 2014) and 104.1 tons/ha in Australia (Woodroffe 1985). The AGB of Thane creek, Maharashtra was estimated as 54.9 tons/ha (Pachpande & Pejaver 2015). Authors such as Chmura et al. (2003), Bouillon et al. (2008), Duarte et al. (2009), Murdiyarso et al. (2009), Kennesy et al. (2010), Chen et al. (2012), and Kauffman & Donato (2012) have highlighted that though mangroves represent small geographical areas, they are capable of high potential carbon sequestration. The average AGB of Kanika Island was 8.261 tons/ha which is less than the above said mangroves.

Diversity indices

Alpha diversity index was highest for site-VI (2.113) due to the occurrence of seven different species and site-II had the lowest value of 0.198 due to the homogeneous vegetation consisting of *A. marina*. Simpson's Index shows the highest value of 1.000 in site-II due to occurrence of large woody trees consisting of *A. marina*. Site-V had the lowest index value 0.297 due to presence of large number of herbs with less girth. Diversity indices revealed that the vegetation of all the study sites was varied and hence the vegetation is heterogeneous in nature (Table 2).

Importance Value Index (IVI)

Out of 12 species enumerated, *A. marina* had the highest IVI of 126.91, followed by *A. alba* (45.59), *A. ilicifolius* (26.69), and *P. pinnata* (17.89) while the remaining eight species had IVI of less than 15.58. *Avicennia officinalis* had the lowest IVI of 5.63. The IVI depicts the ecological importance of a species in a given ecosystem and also helps give conservation priority to the species (Malimbwi et al. 2005; Kacholi 2013). In the present study, *A. marina* and *A. alba* showed high IVI due to their higher relative frequency, relative density, and relative basal area. The IVI of *A. marina* and *A. alba* in Thakurdia mangroves in Odisha were 8.2 and 19.73, respectively (Mishra et al. 2005), whereas the IVI of *A. marina* and *A. alba* were found to be 126.91 and 45.59 on Kanika Island, respectively. It indicates that *A. marina* and *A. alba* enjoy pre-dominance in Kanika island and the reasons for their dominance needs further study.

The analysis of community structure of mangroves at six study sites (0.6 ha) revealed that the relative density of *A. marina* and *A. alba* were higher than the remaining 10 species. It clearly indicates that the mangrove vegetation in Kanika island is characterized by the dominance of *A. marina* and *A. alba.* Eight mangrove associate species were recorded in addition to the species recorded in all six quadrats. *Derris scandens* was observed in close association with mangroves. *Ipoemea pes-caprae*, *H. tiliaceus*, *C. inerme*, *P. pinnata*, *T. populnea*, *S. bacciformis*, *S. maritima*, *S. portulacastrum*, *C. rosea*, and *L. sarmentosa* occurred on the sand dunes and sand bars in the elevated region of the island. Individuals with stunted growth of *P. pinnata* and *T. populnea* were found in the elevated areas. *Sauropus bacciformis* was found in the dried muddy regions of the island. Only one species of grass *A. lagopoides* (Poaceae) was found in the dried muddy areas (Table 2).

True Mangrove vs. Mangrove Associates

Ragavan et al. (2016) had stated that there are 35 true mangrove species in Sunderbans, 35 species in Odisha, 16 species in Karnataka, 19 species in Kerala, 22 species in Andhra Pradesh (Swain et al. 2008), 17 species in Pichavaram, Tamil Nadu (Salachandran et al. 2009), and 16 species in Goa (Sanjappa et al. 2011). But in the present study, out of 20 species counted, only four species—*A. alba*, *A. marina*, *A. officinalis*, and *L. littorea*—were found to be true mangroves and the remaining 16 species were only mangrove associates (Table 1). The occurrence of less number (4) of true mangrove species may be due to the small extent of Kanika Island. In the present study, *P. juliflora* trees also occur in the elevated sandy beach (site-VI). Since there is no human habitation in Kanika Island, the possibility of introduction of these species by humans is very less. Hence, there might be possibility of dispersal of seeds from inland to this island by river water. The impact of *P. juliflora* on the mangrove ecosystem in the study area requires sustained monitoring and further studies (Image 2).

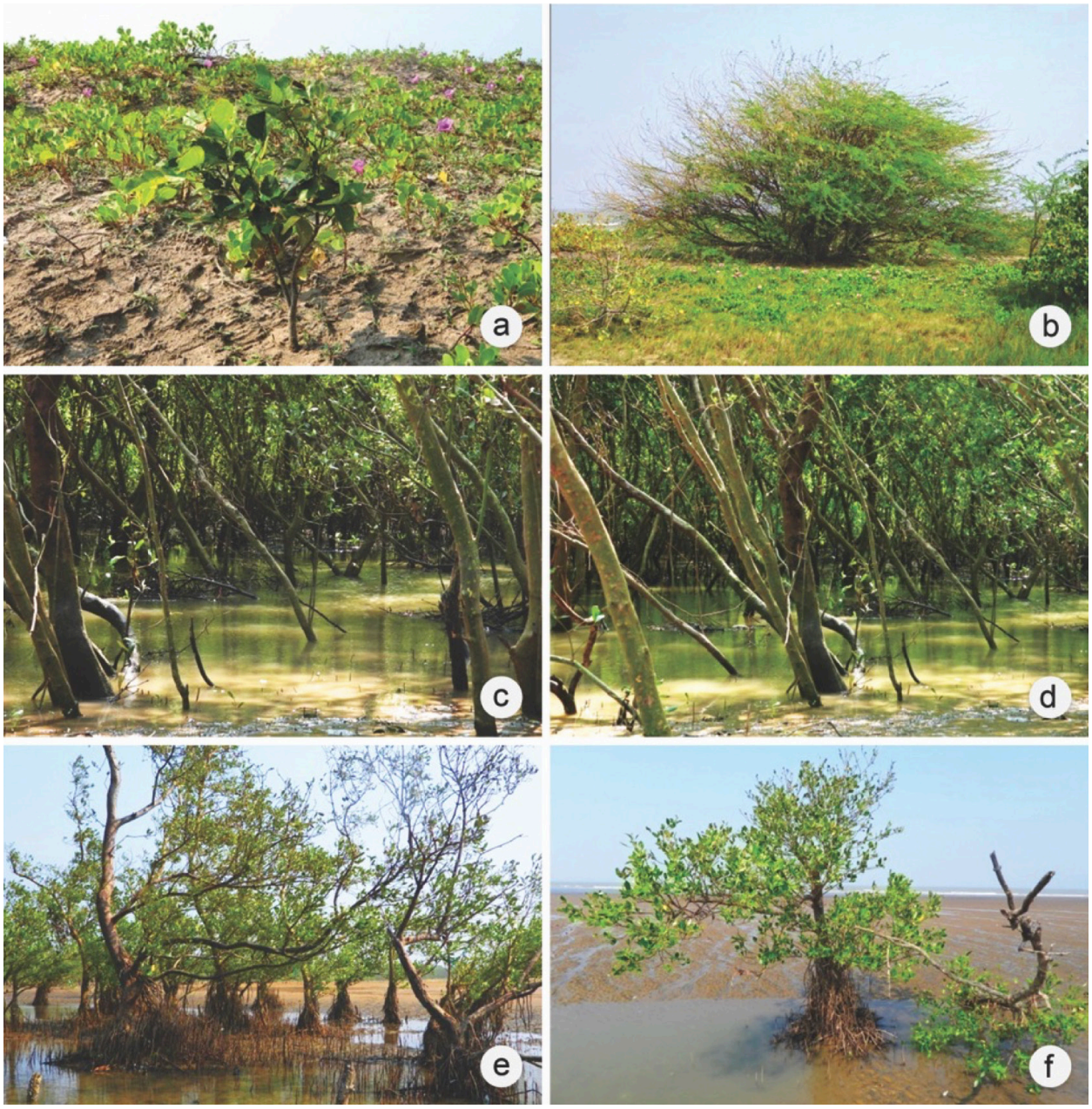

Image 2. Mangrove and mangrove associates in Kanika Island: a—Spread of *Ipomoea pes-caprae* and *Pongamia pinnata* individuals on sand bar | b—Growth of *Prosopis juliflora* tree | c & d—*Avicennia alba* and *Avicennia marina* trees | e & f—Damaged and dead trees of *Avicennia marina* due to erosion. © P. Poornima.

Regeneration of mangroves

The study on the mature (≥1 m height) and juvenile (≤1 m height) individuals of *A. marina* and *A. alba* revealed that *A. marina* had the highest percentage of juveniles than *A. alba*. No juveniles of *A. officinalis* were found in the study sites. Most of the juveniles were found in the exposed areas adjacent to dense mangroves. This may be due to the fact that the seedlings found in open areas grow faster than those under canopy (Ellison & Farnsworth 1993, 1996). If the number of seedlings/saplings of a particular mangrove species is greater than 50% of their mature trees/ha, it is considered to possess good regeneration potential (Gan 1995). In the present study, 92% (n= 609) individuals of *A. marina* and 58.1% (n= 18) individuals of *A. alba* were found to be juveniles. It indicates that these two species were found dominant and have potential for regeneration in the Island as stated by Gan (1995). Apart from natural regeneration some seedlings also found washed into the shore by waves. Seedlings found in open areas grow faster than those

Image 3. Regeneration of mangrove on Kanika Island: a—Deposition of seeds of *Avicennia marina* on sandy beach | b—Germination of a seed | c & d—Natural growth of juveniles in the peripheral muds. © P. Poornima.

under canopy (Ellison & Farnsworth 1993, 1996). In the present observations of seedlings found in the exposed areas corroborate the findings of Ellison & Farnsworth (1993, 1996).

The regeneration potentials of such seeds in inter tidal zones require further studies. It was observed that 13 matured *A. marina* trees were found damaged due to erosion of waves and of them, four were found dead. Since there is no anthropogenic pressure in the Island, the sea erosion related threats to the mangrove may pose a major management challenge in the near future (Image 3).

IUCN status

The IUCN Red List of Threatened Species has classified the status of *A. alba, A. officinalis, A. marina*, and *L. littorea* as 'Least Concern'. These four mangroves are a common occurrence in all the mangrove vegetations of eastern and western coasts and Andaman & Nicobar Islands. Apart from India, *A. marina* is distributed in Australia, Indonesia, Thailand, Malaysia, Singapore, Philippines, and China. *Avicennia alba* is found in all the above said countries except China (Ragavan et al. 2016). Seven species were not evaluated and *P. juliflora* is an invasive alien species. Kanika Island has been considered ecologically sensitive as it provides habitat for several mangrove species (Table 1).

CONCLUSION

My study provides an overview of mangrove species diversity in Kanika Island, Odisha. This Island harbors four true mangroves and 16 mangrove associates. The dominance of *A. marina* and *A. alba* is indicative of species robustness where other species have failed to colonize. The status and species composition of mangrove forest is a basic requirement and a pre-requisite for effective long-term monitoring, management and conservation of mangrove resources. It is suggested that immediate attention should be given for strengthening research activities to build database on true mangrove and mangrove associates. Since the island is uninhabited and free from cattle, there is no anthropogenic pressure on this mangrove vegetation. However, the fishing activities around the island should be regulated without causing

any harm to the fragile mangrove ecosystem.

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